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THE ORIENTATION OF BUILDINGS ON THE BASIS OF SUNLIGHT

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The value of sunlight to both anmial and vegetable kingdom has always been recognized, but very often not fully appreciated. We know that it is beneficial to get much sunlight, but very few of us know just how much we are getting under any one set of conditions, nor do we know whether we are getting more of less than under another set of conditions.

It was with this in mind, that it seemed desirable to ascertain the relative amounts of direct sunlight entering a vertical window when the window was facing in one direction in one case and in some other direction in another case.

To conduct this work it was necessary to know the exact azimuth and altitude of the sun at any moment throughout the day of any day in the year. It was also necessary to know what part of the light was absorbed by the atmosphere, what per cent of the total possible sunshine hours the sky was clear, and what part of the incident light was absorbed by the window glass.

To get the total light flux entering a house at any moment it was necessary then to obtain the product of the following:

(a) the cos of the azimuth of the sun;
(b) the cos of the altitude of the sun;
(c) percent of the solar light flux transmitted through the air;
(d) the percent of the total time possible that the sky is clear;
(e) the percent of the incident light flux transmitted through glass.

For part of this work use was made of a celestial sphere 3 ft. in diameter. From this the azimuth and altitude of the sun in the heavens at any moment could be read off. It was set correctly for Iowa State College which is at a latitude of 42° N.

For the air transmission, use was made of the relation that a homogeneous layer of air 5 mi. thick and having the density of air at sea level, will absorb just as much light as the atmosphere actually does absorb under existing conditions. From the expression $I_x = I_0 a^x$, one could determine the part transmitted at any altitude. In this equation I_x is the intensity reaching the earth, I_0

the intensity reaching the outer layer of the atmosphere, a is the transmission coefficient, and x the number of layers. Langley gives 0.67 as the value for I_x. Since I_0 is unity and x was taken as 5 mi., a was found to be 0.923. The upper curve in Fig. I is a typical curve for the sunlight obtained throughout a clear March 21. The ordinates indicate the fraction of the total possible sunlight entering a vertical south facing opening which is not glassed.

The abscissae represent the time of day. The area underneath the curve represents the total light flux for the day in question. This is plotted as ordinate in Fig. 2, where the uppermost curve shows how the light flux varies throughout the year for a southern exposure. The area under this curve gives the total light flux for the year assuming only clear days and for vertical openings where no glass windows are used.

From the Iowa Weather and Crop Report for Des Moines we note that over a period of 16 years (1906-1921) the average per cent of clear sky per month is as follows:

Jan.	52 percent	April	58 percent	July	77 percent	October	62 percent
Feb.	55 percent	May	62 percent	August	72 percent	Nov.	54 percent
March	61 percent	June	68 percent	Sept.	62 percent	Dec.	49 percent

When these figures are applied to the uppermost curve in Fig. 2, the middle curve is obtained. The area underneath this curve is proportional to the *total annual flux* of light received through a vertical unglassed opening. This would be of interest in determining the amount of light entering the rows of trees in an orchard, the amount of light entering the streets in our cities, or the amount entering vertical openings in hog houses or sheep barns.

Next we must consider the effect produced by glass window panes. In this work 4 per cent was allowed for absorption by the glass. The table given on p. 579 of the ninth edition of "Handbook of Chemistry and Physics," published by the Chemical Rubber Pub. Co., furnished the data for reflection of light from glass at various angles of incidence. When applying these figures to the upper curve in Fig. 1 we get the lower curve. If now we carry this over to Fig. 2, we get the lowest curve in that figure. Thus the area underneath the lowest curve is proportional to the total annual luminous flux received into a room through a vertical window.

All the above was for one (south) orientation only. Since, when facing another direction several of the factors changed, the whole system had to be repeated for each direction used. Curves

were plotted for all these cases but the ones given here are typical of the general system of curves and are considered sufficient to represent the idea.

The normal intensity of sunlight on the earth's surface as measured with an illuminometer was found to be approximately 6700 ft. candles. With this as basis the total annual luminous flux entering a vertical south facing opening was found to be 439×10^4 lumen hours per sq. ft. When considering the glass window panes the following are the values obtained:

South facing.....	348 x 10^4 lumen hrs. per sq. ft.	41.
S. S. E. facing.....	348 x 10^4 lumen hrs. per sq. ft.	41.
S. E. facing.....	331 x 10^4 lumen hrs. per sq. ft.	39
E. facing.....	228 x 10^4 lumen hrs. per sq. ft.	27
N. E. facing.....	80 x 10^4 lumen hrs. per sq. ft.	9.4
N. facing.....	8.5 x 10^4 lumen hrs. per sq. ft.	1.0

The numbers in the extreme right hand column give the ratio between the values in the other part of the table, thus indicating that 41 times as much *sunlight* enters a south facing window than enters one that faces north. Fig. 3 represents these results graphically.

In curve *a* of Fig. 3 the radii represents the sunlight flux entering a vertical opening when the orientation is as specified on the curve and assuming that all days are clear. Curve *b* is the same but cloudiness is here considered. Curve *c* represents the same when both cloudiness and glass windows in the opening are considered.

Curve *d* represents the flux due to direct sunlight and in addition that due to daylight whether that be due to a gray sky or a clear sky.

Curve *d* was obtained by making use of the light intensity due to a clear sky and also that due to a cloudy sky. A clear sky is found to produce a light flux approximately equal to 0.1 that of direct sunlight and a cloudy sky varies from much below a clear sky to much above a clear sky. Both clear sky and cloudy sky may be assumed to be equal to 0.1 that of direct sunlight.

By making use of curve *d* in Fig. 3 one can readily determine which way to face windows under any conditions to get maximum daylight into the space under consideration.

1. When a house has windows on one side only — face them south.

2. When a house has windows on two opposite sides only — face them east and west.

3. When a house has windows on two adjacent sides only — face them southeast and southwest.

4. When a house has windows on three sides only — face them east, south and west.

5. When a house has an equal number of windows on each side it is immaterial how the house is oriented.

Curves *a, b, c,* can be used similarly to get the optimum orientation for their respective conditions.

After getting a curve like the lowest in Fig. 2, for several orientations one can determine the variation in the amount of sunlight entering a window throughout the year. The table given herewith shows the variation from maximum.

S. facin..... 62 percent	S. S. E. facing..... 48 percent
S. E. facing..... 56 percent	E. facing..... 89 percent
N. E. facing.....100 percent	N. facing.....100 percent

Again if to the ordinates for the lowest curve in Fig. 2 we can add an amount representing the value of *skylight* for each date plotted we can get the variation in the total amount of natural light entering a window throughout the year. The ordinate to be added at each date was calculated and it was found that the variation from maximum in the total amount of light entering a window throughout the year was as follows:

S. facing.....35.8 percent	S. S. E. facing.....35.6 percent
S. E. facing.....42 percent	E. facing.....69 percent
N. E. facing.....65 percent	N. facing.....48 percent

The importance of this point can readily be seen when we consider that it is desirable to have little variation from week to week in the light flux entering windows in tubercular sanitaria.

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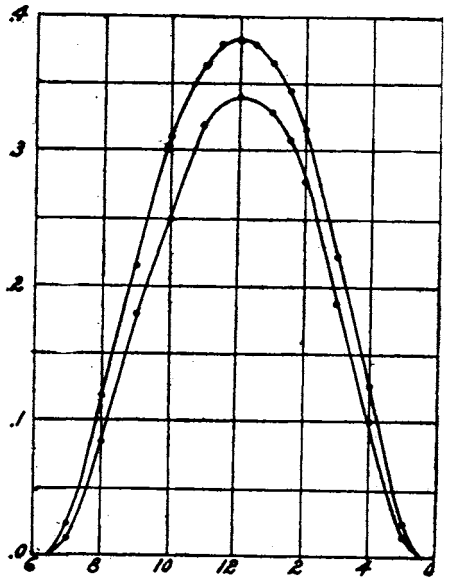

Fig. 1

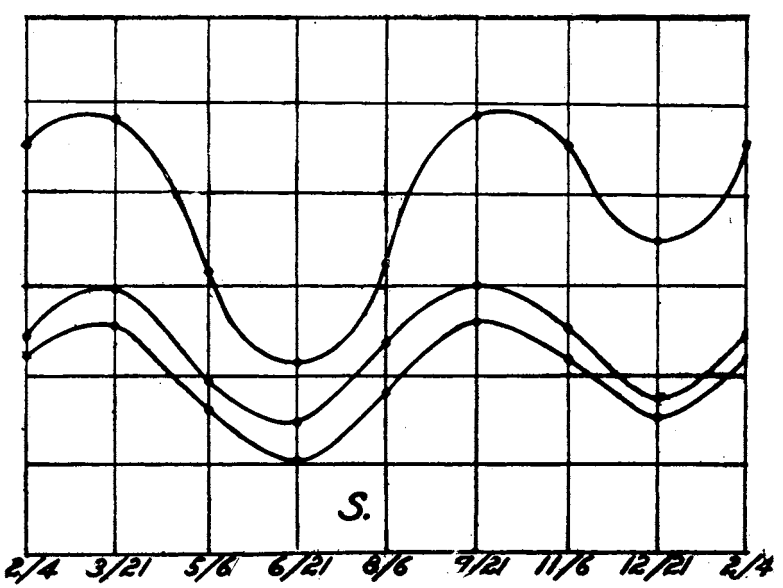

Fig. 2

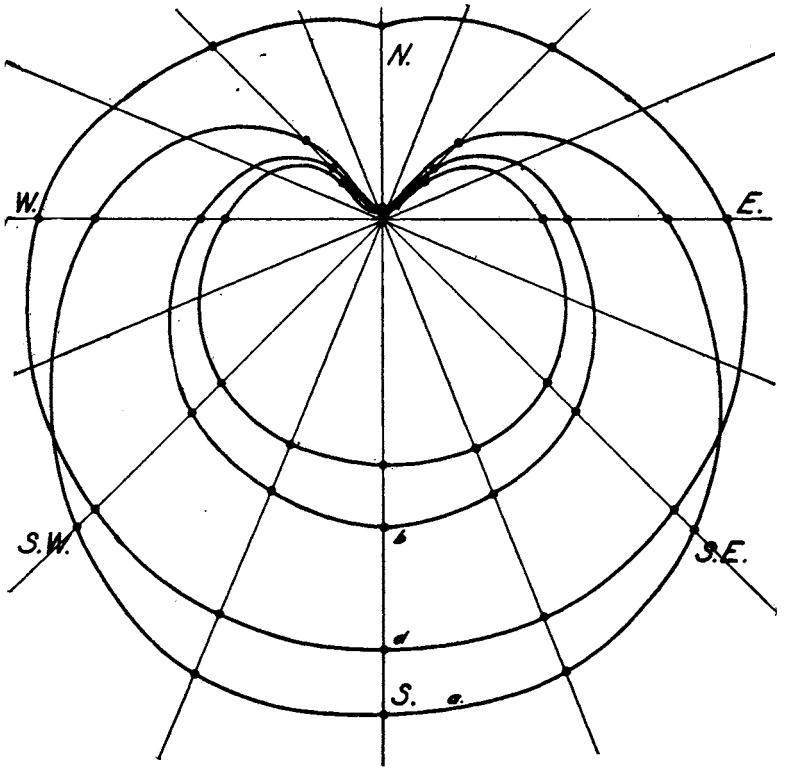

Fig. 3